DEFORESTATION AND SUSTAINABLE MIXED-USE LANDSCAPES: A VIEW FROM THE EASTERN HIMALAYA[1]

Kamaljit S. Bawa[2,3,4] *and Reinmar Seidler*[2]

ABSTRACT

The interrelationships between smallholder agriculture, forest cover, and biodiversity loss have received insufficient research and analytic attention, though they stand at the center of the ongoing biodiversity crisis in tropical landscapes. Despite important advances in conservation science, knowledge generation remains fragmentary, and the formal institutions concerned with agriculture, forestry, social change, and climate change continue to work to a large extent in isolation, especially in developing countries. Drawing on our research program in the montane Eastern Himalaya of India, for example, two questions are explored: What types of landscapes can provide livelihood security for growing populations while maintaining healthy ecosystems? What kinds of knowledge, institutions, and policies will help us move toward land-use patterns that support livelihoods and protect biodiversity, given a regional economy based on small-scale agriculture? Here, we advocate for a greater integration of knowledge types (scientific, traditional, and participatory) and institutions (formal and informal, government and community) to foster better planning in order to reconcile several functions at the landscape level, including smallholder agriculture, the production of ecosystem goods and services, and the protection of biodiversity.

Key words: Biodiversity loss, ecosystem services, Eastern Himalaya, land-use patterns, smallholder agriculture, sustainable landscapes, usable knowledge.

THE PROBLEM: TROPICAL BIODIVERSITY LOSS

The last few decades have witnessed tremendous advances in conservation science and increased awareness of the importance of biodiversity and ecosystem services (defined by the Millennium Ecosystem Assessment [2005] as the "benefits people derive from natural ecosystems," and by The Economics of Ecosystems and Biodiversity [TEEB; 2010] as the "contributions of ecosystems to human wellbeing"). Policies and governance for biodiversity conservation are improving slowly and unevenly. However, there is little evidence that the rate of biodiversity loss in the form of deforestation or forest degradation, especially in the tropics and the subtropics, has declined. Hansen et al. (2008) estimated tropical forest loss at 73,000 km^2/year between 1990 and 1997, with a reforestation rate of only 10,600 km^2/year during the same period (the reforested areas including both naturally regenerating forests and tree plantations). A more recent analysis of global forest loss between 2000 and 2005 found a total loss of 95,000 km^2/year of humid and dry tropical forest over the five years, starting with 18,699,000 km^2 of total forest biome area in 2000 and amounting to a 2.5% loss of that total (Hansen et al., 2010). In the latter analysis, "forest" was defined as 25% canopy cover with trees at least 15 m in height. Because of the slow rate of growth in forest vegetation, increases due to regeneration or tree plantations were not included.

However, deforestation is a very gross measure of biodiversity loss. Selective logging, too, exerts a series of effects that may degrade not only the logged area but also adjoining areas. In the humid tropics, where commercial stems may be widely separated, Asner et al. (2010) estimated the overall area affected by selective logging to be 20 times that of outright deforestation. Invasive species, too, are responsible for the degradation of forests in many tropical regions. Remote sensing methods currently used to monitor global forest loss are unable to detect the more subtle changes in forest condition due to these forms of forest degradation, though they can also result in biodiversity loss. (See Kimothi et al. [2010], however, for evidence of steps toward this technical capacity.)

Much of the net reduction in tropical forest cover until now has been due to shifting land-use patterns. In the future, climate change is likely to exert major additional and complicating impacts on tropical

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[2] Department of Biology, University of Massachusetts, Boston, Massachusetts 02125, U.S.A. Author for correspondence: kamal.bawa@gmail.com.

[3] Ashoka Trust for Research in Ecology and the Environment, Bangalore, India.

[4] Sustainability Science Program, Harvard University, Cambridge, Massachusetts 02138, U.S.A.

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forests. Asner et al. (2010) calculated that by 2100, the combined effects of climate change and land-use change (e.g., agriculture and selective logging) could negatively affect at least three fourths of tropical humid forest: up to 81% in Amazonia, 74% in the Congo Basin, and 77% in Asia-Oceania. Thus, according to Asner et al.'s modeling exercise based on 16 general circulation models (GCMs), by the end of this century only around 20% of the tropical humid biome is likely to remain unaffected by combined climate and land-use changes.

CHANGING KEY DRIVERS

Agriculture clearly remains one of the key drivers of land-use change (Lambin et al., 2001). Growing human populations, increasing consumption, and rising competition in land uses for biofuels and livestock feed production will inevitably continue to exert pressure on tropical forests (Food and Agriculture of the United Nations [FAO], 2011). At the same time, smallholder agriculture has been a major driver of deforestation in the tropics, especially in Asia in the 1970s and 1980s (Bawa & Dayanandan, 1997). Yet, the contemporary magnitude of deforestation by small farmers in tropical Asia remains controversial and difficult to estimate. Smallholder activity in the tropics is fluid, especially in areas remote from population centers and close to forest margins. It responds to a shifting array of social, economic, and ecological cues, many of them remotely generated. Global and regional measures of forest loss, thus, tend to conceal the complexity and dynamism of forest change patterns.

THE CONTEXT: EASTERN HIMALAYA

We have chosen the Eastern Himalayan region in India to address the intersecting issues of deforestation, poverty, and agriculture within the context of conservation of biodiversity and associated ecosystem services. In the Darjeeling Hills of northern West Bengal, in the Indian state of Sikkim and in the Nepali border province of Ilam, lowland humid evergreen forests (dominated by *sal*) mount steeply through species-rich moist maple-oak-rhododendron forests to high-altitude rhododendron and alpine conifer associations. Strictly speaking, much of this area falls at the borderline of the tropics due to its altitude-dependent winter frosts and snows. The regional "hill culture" is dominated by Nepali, Tibetan, and Bhutanese influences, rather than by the Indian culture of the "plains." Nevertheless, both natural and traditional social/agricultural systems throughout the Eastern Himalaya have been regulated principally by the strong annual monsoon, and the flora is a varied mix of Indian Peninsular, Indo-Burmese, Palearctic, and Far Eastern elements. Here, biodiversity-rich montane landscapes are dominated by small farms, generally less than 0.5 ha each. These are interspersed with forests and other land uses, primarily commercial tea plantations. Over the last several decades, smallholder agriculture and the collection of fuel wood and fodder from the forest have been major drivers of regional land-use transitions. Behind these drivers lie population growth, trade, and inadequate governance.

The main argument here is that the interaction between small-scale agriculture and biodiversity change remains largely unexplored with reference to two questions: What types of landscapes can provide livelihood security for growing populations while sustaining critical ecosystem services? What types of knowledge, institutions, and policies may help us move toward land-use patterns that support livelihoods and protect biodiversity, given a regional economy based on small-scale agriculture?

We believe that research and action focused at the interface of biodiversity and small-scale agriculture have the potential to point the way toward effective biodiversity conservation measures in populous tropical nations. Although our analysis is site-specific, the conclusions we draw are applicable to other parts of the world with similar landscapes and can be applied to a variety of social and economic contexts.

PEOPLE, LAND USES, AND LANDSCAPES

The total magnitude of deforestation in India in general, and in the Himalayas in particular, remains uncertain, due primarily to conflicting estimates. The Forest Survey of India (FSI), a government agency, makes an assessment of land cover change every two years. Based on these assessments, it appears that net Indian forest area has remained stable over recent years (FSI, 2009). However, the latest analysis of deforestation by independent researchers indicates an annual deforestation rate of 1.5%–2.7%, which is consistent with earlier independent estimates (Puyravaud et al., 2010).

For the Himalayas, data are scarce. The few available studies indicate that forest loss and degradation have continued until recently (Prabhakar et al., 2006; Pandit et al., 2007). Baland et al. (2010) found that over one half of a forest sampled in Himachal Pradesh and Uttaranchal was highly degraded in terms of reduced canopy cover and increased cutting of branches and twigs for fuel and fodder, although basal area remained relatively

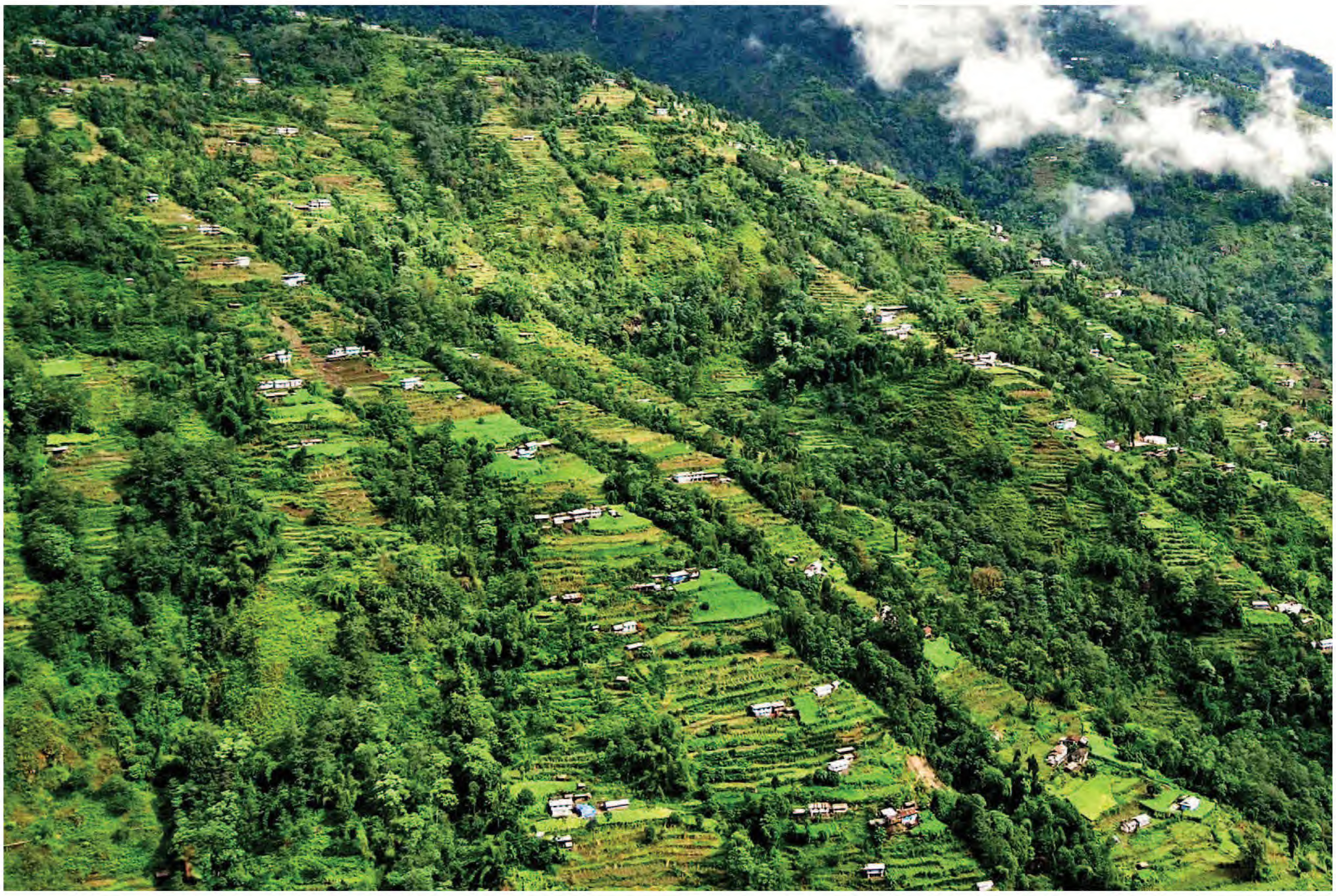

Figure 1. Typical mixed-use agricultural landscape in Darjeeling Hills, northern West Bengal, 2011.

unaffected. Smaller-scale studies, however, show countervailing and sometimes contradictory trends. The analyses by Nagendra et al. (2009) for a protected area and forest reserve between 1990 and 2000 indicated an increase in forest area in some parts of the reserve but also increased fragmentation in the same areas. Our own analysis for a different region in the Himalayas indicates continuing deforestation from 1990 to 2005 (Chaudhary, Shrestha & Bawa, unpublished data).

Throughout the Eastern Himalayas, population growth has been pushing farm boundaries into forests. As always, grazing and gathering of biomass for fuel and fodder advance ahead of the agricultural "frontier" itself. In recent years, at the landscape level, hydroelectric dams and associated infrastructure such as roads and tourism developments have become major additional drivers of biodiversity change. In many areas, the forest understory is dominated by invasive native and alien species of bamboos and shrubs. These also invade landslips and logged forests.

SUSTAINABLE LANDSCAPES

Within this context, what specific meaning might the concept of a "sustainable landscape" carry? The term has entered common usage, but like the concept of sustainability itself, it is poorly defined due to multiple competing definitions. We define sustainable landscapes as those covering tens of square kilometers or more that sustain food production, provide biodiversity-rich habitats, and maintain ecosystem services (fresh water, soil retention and fertility, fuel wood, fodder, and other non-timber forest products [NTFP]) for current and future generations. Other attributes based on biophysical characteristics include provision of livelihood security and resilience to climate change. A further category of attributes, including social justice and equity of resource access, belongs more particularly to the institutions that govern sustainable landscapes, yet these, too, will presumably be expressed in the spatial organization of sustainable land uses (Ostrom & Nagendra, 2006; Turner et al., 2007).

Figure 1 shows a typical landscape of the Singalila Range of the Eastern Himalayas in 2011. The landscape represents a mix of agricultural production with fairly high biodiversity value and the continued maintenance of important ecosystem services. A hundred years ago this landscape consisted almost exclusively of forest. Today, many small forest fragments, orchards, and individual trees are interspersed among houses, small agricultural fields, gardens and terraces, patches of degraded vegetation, etc. Forest copses generally remain on the steepest slopes, especially along the streams that have cut steep-sided channels through the erodible sedimentary soils. One of the most noticeable aspects of these Himalayan landscapes is the extreme steepness of much of the topography. It forces human habitation to cling perilously, and ingeniously, to the least precipitous slopes available.

Socio-ecological interactions and political and economic forces have generated the current configuration of land uses over several generations. Although this landscape appears to be "balancing" several functions (i.e., "reconciling" rather than "optimizing"), it is a landscape in flux and under considerable demographic and extractive pressure, supported by fragile regulatory frameworks. Whether or not further deforestation can be curtailed in this landscape will largely depend upon efforts to alleviate poverty, biophysical factors, future population growth, flows of goods and services to and from surrounding landscapes, socio-ecological resilience to climate change, and other potential challenges, and on the enabling knowledge, institutions, and policies.

POVERTY ALLEVIATION

The average annual income of rural households such as those shown in Figure 1 is approximately Rs48,000 (under US$800 in 2014), very close to the poverty line as defined by the Government of India. Landscapes such as these cannot be considered sustainable when the vast majority of their inhabitants live in poverty. The spatial correlation between biodiversity and poverty is widespread and not confined to the Eastern Himalayas (Sachs et al., 2009). With limited land, the few options to raise household income include increasing the productivity of the land and producing a diversified portfolio of goods and services (Bawa et al., 2012). However, the effects of poverty on forests are complex and variable (Chomitz, 2007; Roe, 2008), and poverty alleviation cannot independently make the landscape sustainable.

BIOPHYSICAL FACTORS

The long-term productivity and ecological efficiency of any landscape-scale arrangement will depend partly on how closely the distribution of land uses corresponds to the underlying productive potential of particular patches, including soil nutrient availability, hydrology, prevailing local climate factors, slope, and aspect, etc. Natural forest in the Eastern Himalaya is highly diverse, patchy, and dynamic, due both to the variety of volcanic and alluvial soil types and to frequent landslips, which expose or truncate soils on steep slopes with thin organic soil horizons (Singh & Singh, 1981). The region experiences heavy monsoon-season rainfall, and frequent seismic activity also contributes to soil erosion (Burbank et al., 2012). Agriculture has extended onto high and steep slopes requiring the adoption of labor-intensive measures such as terracing and earth bunds to prevent surface soil erosion (Mandal & Sharda, 2011). While short-term productive potential is probably not being maximized in our landscape, medium-productivity rates together with a degree of longer-term security may have been attained. Questions about biophysical limits to sustainability, however, require empirical data.

POPULATION TRAJECTORY

During the last 50 years the population in the Eastern Himalayan states of India has tripled, though with a declining growth rate since the 1960s (Goel, 2005). In the rural landscape shown in Figure 1, our results indicate that population size has almost doubled during the same time period, primarily due to growth and multiplication of original households in the area rather than immigration. In Darjeeling District as a whole, the decadal population growth rate decreased from 24% in 1991–2001 to 14% in 2001–2011. In the adjoining state of Sikkim, the average growth rate from 2001 to 2011 was only about one third of the growth rate over the previous decade. In the Darjeeling Hills, for which detailed data are available only until 2001, population growth was unevenly distributed. Darjeeling town grew at 45% over the decade to 2001, and rural parts of the southern plains and the fertile agricultural areas around Kalimpong also grew rapidly (~26%), while there was slight negative growth (~1%) in the high hills toward Singalila, north and west of Darjeeling town (the site shown in Fig. 1). If the population stabilizes during the next decade or two, with a modest increase in the productivity of agriculture, such landscapes combining a mixture of agricultural lands and native forests and watersheds could be maintained.

FLOWS OF GOODS AND SERVICES

The rural landscape shown in Figure 1 is by no means a closed system. Along with the flow of human inhabitants, a variety of material stocks and ecosystem services flow both into and out of the region. The high slopes are still clothed in forest, from which dry-season water flows remain significant. Streams carry sediments downstream that constantly nurtures and renews soils in river valleys and lowlands. Other significant services include pollinators and natural predators of pests. The aesthetic, spiritual, and religious importance of the Himalayan landscapes is enormous.

Ecosystem "services" are not invariably beneficial to human populations. While monsoon-season floods spread fertile sediments on agricultural fields throughout the Eastern Himalayan foothills, they can also cause considerable devastation. Wildfires clear forest understory and help improve the fertility of soils for planting. Yet protecting themselves from the destructive impacts of these natural forces is one of the primary goals of cultures worldwide. In the unprotected river valleys of the Himalayan foothills, the areas closest to the riverbanks are occupied by the most marginalized segments of society (e.g., Kalita et al., 2010). Risk of disastrous flooding is an ever-present aspect of their lives, and they are often a constituency for multi-purpose dams and other water development projects that promise some degree of human control over their environment. Similarly, biodiversity itself is no unambiguous "good" for those living in close contact with it. Many animals are destructive of crops or livestock. Others compete directly with people for high-value natural resources. Non-commercial plants may compete successfully with economically useful ones. People everywhere seek to increase their control over potentially dangerous natural forces.

Furthermore, protecting biodiversity and protecting ecosystem services are by no means synonymous. High levels of ecosystem services can often be provided through careful management of agricultural land, but managing agricultural landscapes for the associated ecosystem services does not automatically protect wild biodiversity (Buck et al., 2006). Thus, most people aspire to live in areas with controlled, predictable flows of useful natural services; this tends to mean multifunctional landscapes with mosaics of different land use intensities at the local scale.

There is a net flow of positive ecosystem services out of the Eastern Himalayan montane region (including water, soil nutrients, carbon sequestration, pollinators, and eco-tourism) as well as a variety of goods that directly support the agricultural system (Bawa et al., 2007). Local people contribute to the maintenance of these services while at times suffering from the disservices (in particular, floods and human-wildlife conflict). To the extent that they contribute to the maintenance of valuable services, individuals and communities may be said to be "producing" ecosystem services or habitats. A more formalized system of compensation by society, such as that is already in existence across the developed world in the form of conservation easements, subsidies, and offsets, would go a long way in maintaining these types of mixed-use landscapes (Naidoo et al., 2006; Wunder, 2007). This, however, puts a premium on institutions capable of organizing, assessing, and dispensing compensation, outputs related to the institutional frameworks discussed in a later section.

CLIMATE CHANGE AND RESILIENCE

To a large extent, resilience to climate change remains an undefined parameter (see, e.g., Moench and Dixit [2007] for a summary of the issues). Making the concept of sustainable landscapes operational will, thus, require the development of new kinds of knowledge and institutional forms. In the Eastern Himalayas, residents are aware of changing meteorological trends, and they are interpreting them as the onset of climate change (Chaudhary & Bawa, 2011; Chaudhary et al., 2011). Inhabitants are beginning to adapt their agricultural strategies to the changing conditions, generally making adjustments at the household level and within the limits of the traditional response patterns and technologies available to them. If climate-related changes continue and exceed the bounds of historical variability, they will certainly place new stresses on institutional resources. In particular, the ability of government and non-governmental and community agencies to successfully communicate and cooperate when responding to extreme events will be challenged. In much of this region, extremes are expected to come in the form of increased flooding and landslides. However, there will likely be a good deal of local variability. Advances in the precision of regional level climate modeling are sorely needed.

Toward Sustainable Solutions: Knowledge and Institutions

In a thoughtful essay, Sayer et al. (2008) pointed out that conservation biology has become quite sophisticated in its ability to identify and quantify threats and to characterize the distribution and function of biodiversity, but it has placed much less emphasis on defining and articulating desired outcomes. Such outcomes require integration of knowledge across disciplines (biological, social, and political), knowledge systems (scientific and traditional), and spatial (regional and local) scales (Bawa et al., 2012). However, our ways of generating and distributing knowledge remain fragmentary. For example, even among the ecological sciences, land use change, biodiversity change, and climate change are often studied as separate domains and are frequently monitored separately, especially in developing countries, though their drivers and effects are intimately intertwined. Livelihoods, agriculture, and biodiversity, too, remain conceptually separate, despite the fact that it is precisely the interactions among these domains (expressed through the actions of small farmers and policy makers) that generate the type of landscape shown in Figure 1.

Furthermore, the incentives to which small-holders respond are not necessarily amenable to observation and analysis by non-governmental organizations (NGOs) or government agencies not based in the region or with a long-term presence there. Assessing the potential of landscapes for sustainability requires information that can only be gathered through participatory processes. Consequently, our ability to generate usable knowledge to help civil society imagine, choose among, and move toward positive options has remained relatively limited.

The processes and institutional frameworks needed for producing integrated knowledge and action largely remain to be developed, particularly in developing countries (Bawa et al., 2008). Apart from generating relevant knowledge, we urgently need to develop institutions capable of making the links with action to support sustainable landscapes.

INSTITUTIONS FOR SUSTAINABLE LANDSCAPES

What is "usable knowledge"? By definition, it incorporates due consideration by society and particularly by policy makers (Clark et al., 2011). Because knowledge that contributes to sustainability is often still divided into separate domains, in many countries separate government agencies have to deal with agriculture, forestry, and water, to name a few. Furthermore, although markets, financial incentives, and disincentives play important roles in shaping landscapes, agencies dealing with natural resource management are rarely expected to concern themselves with the social factors underlying the patterns of natural resource use. When they are expected to integrate these factors, as in the administration of the Joint Forest Management Programs (India) and Community Forestry Programs (Nepal), for instance, they are not always well prepared to do so (Ghate, 2003; Lélé et al., 2003). Researchers, for their part, have focused productively on the ways in which formal institutions, such as legal tenure systems, land markets, and governance, contribute to landscape organization (Agrawal & Chhatre, 2006; Ostrom & Nagendra, 2006), but the roles of informal institutions, such as social and kinship networks, and the subject of customary rights have received less attention, perhaps because our ability to document their influence remains relatively undeveloped.

Globally, the formal institutions concerned with agriculture, forestry, biodiversity conservation, social change, and climate change tend to work in isolation. Moreover, in the tropics, such institutions still have little or no interaction with local people and local landscapes, even though the United Nations Millennium Development Goals, which incorporate targets of the Convention of Biological Diversity (CBD), call for just such integration. There is great scope in the developing world for knowledge-generating institutions to develop, nurture, and promote interdisciplinary knowledge (Bawa et al., 2008).

CONTRASTING MODELS OF LANDSCAPE ORGANIZATION

How are institutional frameworks reflected in specific patterns of landscape organization? Sayer et al. (2008) contrast a "European model" (consisting of mosaics of discrete land-use patches) with the less well-defined patterns typical of the tropics. Many landscapes in populous tropical areas, including those located around and even inside protected areas, are highly dynamic today (Nagendra et al., 2006). Land-use patterns respond rather sensitively to changing pressures from market forces and population movements. In the Tadoba-Andhari Tiger Reserve in central India, for instance, rates of deforestation and spontaneous reforestation nearly balanced out one another over a 12-year period (Nagendra et al., 2006), but during that time, as much as 16% of the forest area transitioned from one state to the other, either from forested to deforested, or the reverse. Thus, overall forest cover figures may conceal considerable dynamism in land-use patterns.

In contrast, the "European model" of landscape organization has, over several hundred years of relatively slow-paced economic and demographic development, moved toward increased stability of landscape uses at finer and finer scales (Bloch, 1966; Rackham, 1986; Blackbourn, 2006), the "European model" now affords individuals considerable decision-making powers over legally owned lands, but these rights are increasingly heavily qualified by government agencies (including supra-governmental EU agencies) assumed to represent the rights of non-local stakeholders to biodiversity and other ecosystem services, recreation, "heritage," or existence values, and so forth. Restrictions on resource use or development are often compensated by large-scale subsidy instruments, administered contractually (Wunder et al., 2008). This is also increasingly the North American model, particularly in areas such as

New England with a relatively long history of dense settlement. Thus, the dominant trend throughout the industrialized world over the last two generations has been toward greater degrees of state/civil-society planning in response to increases in population density and rising incomes (Schreiber, 1990).

Eastern Himalayan landscapes (particularly in India) are regulated by more general national restrictions on timber harvest, NTFP extraction, and commercial development. There is still relatively little capacity for cadastral services, but in principle, land development above 2000 m elevation is regulated by the Forest Department at the fine scale. In those cases, plots are mostly privately owned, though many areas are in dispute. Legal and illegal agricultural encroachment into forested areas continues to an unknown extent (Oli et al., 2013).

Throughout India, land tenure arrangements are in flux. The Forest Rights Act of 2006 may constitute a significant step toward settling the land tenure rights of a large number of socially marginalized forest dwellers, but it is still being implemented only gradually in many areas (Sarin & Springate-Baginski, 2010; Bawa et al., 2011). If the Act can be completely implemented, and if its prescriptions can in turn be strongly linked with community forest stewardship, employment opportunities, and strengthened collaborative governance initiatives, it will be a big step forward.

In order to fully realize this step, however, informal and community institutions will need to be strengthened almost everywhere. In particular, they will need to build their capacity for collaborative partnerships with government agencies at a larger scale, and the government agencies will need to extend their ability to work creatively with community groups rather than simply dominating them in "participatory" situations, as has too often been the case (Lélé et al., 2003; Nayak & Berkes, 2008).

Conclusion: Getting the Incentives Right

Biodiversity conservation in many densely populated tropical landscapes needs to be understood and pursued as an element, even a driver, of effective economic development. As we move forward, conservation and development can no longer be pursued on separate tracks (Boedhihartono et al., 2007). The importance of securing willing participation from individuals and communities cannot be overestimated if implementation of conservation policies is to be effective. Under conditions of ongoing change, the overall goal must be flexibility and adaptability in land-use patterns considered across whole landscapes; this will require much-improved institutional frameworks and skills in negotiation. Needs and wants (in the Eastern Himalayas and more widely) will only continue to grow in the coming decades. As long as there are natural resources to be extracted and transformed to meet specific desires of local and global economies, enterprising individuals will find ways to gather and market them. Conservation strategies that rely narrowly on protecting resources by restricting their use and consumption, thus limiting economic opportunity, are unlikely to succeed in the middle to longer terms. In order to achieve lasting success in biodiversity conservation goals, incentive systems are needed that can motivate people to protect and regenerate resources, including biodiversity, rather than merely consuming (or degrading) them. "Sustainable use" in rural areas will thus depend less on effective limits to *consumption*, than on effective incentives for the *production* of renewable resources. Any such system of incentives will need to motivate at least "some of the people all of the time" and "all of the people some of the time." Putting such incentives in place will demand a strong emphasis on building the capacity of institutions and key groups to participate actively in knowledge generation and in local land-use planning. It will require an explicit focus on a healthy rural economy in the broadest sense, going well beyond the present system of incentives focused narrowly on the dimension of financial returns.

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